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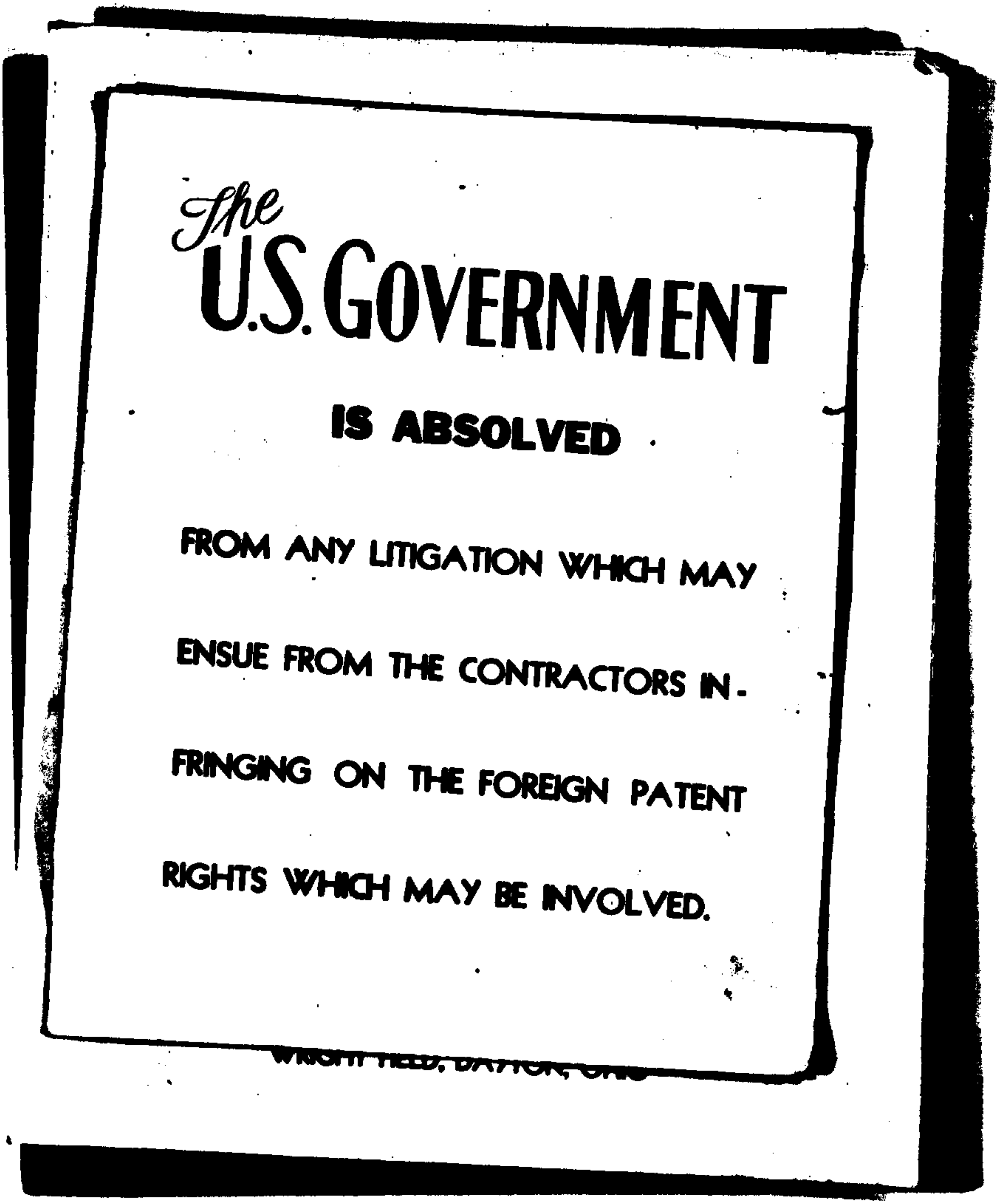

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MEASUREMENTS ON NOISE FROM REFLEX OSCILLATORS

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Report 872   December 21, 1945

MEASUREMENTS ON NOISE FROM REFLEX OSCILLATORS

Abstract

A program of measurements on noise output of reflex local oscillators, particularly the 723A/B and 2K33, was undertaken to try to determine the importance of this factor in receiver design. Considering the two noise sidebands each 2.5 mc/sec wide and located 30 mc/sec away from the main output, we found noise powers ranging from 2.2 to 9.8 x 10^{-12} watts coming out of 723A/B's loaded for optimum output. Asymmetrical behavior of the noise with electronic tuning was investigated and found to require the new theory presented in the companion report number 873 by J. K. Knipp. Some measurements of the individual noise sidebands and of the noise output as a function of load were found to be in satisfactory agreement with theory.

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Title page
15 numbered pages

MEASUREMENTS ON NOISE FROM REFLEX OSCILLATORS

Introduction

Although it has been known for about three years[1] that local oscillators can contribute appreciable noise in microwave receivers, the experimental data have been rather scanty. In view of the fact that the trend to higher radio frequencies and the steady improvement in converters both tend to magnify the importance of this source of noise, it was decided to undertake a measurement program covering particularly the reflex velocity variation tubes used at X and K bands. The recent introduction of balanced mixers which eliminate this noise has greatly reduced the practical importance of this work but nevertheless it may be of interest for the light it affords on the behavior of reflex oscillators. It was intended to study the noise output of a group of tubes under reproducible conditions, to attempt to determine the effects of different tube designs, as well as to obtain numerical information for the use of the set designer. With this in mind measurements with i-f's of 30, 60 and 90 mc were made first on a group of 723A/B tubes and later on some assorted X-band oscillators.

While the measurements were in progress, a paper by Pierce[2] appeared and we devoted considerable effort to attempts to verify his calculations. Our conclusion was that his theory appeared to predict correctly the effects of changes in tube design or load conditions on noise at the center of the electrical tuning range, but that it was incapable of accounting for the large variations we found with electrical tuning. At this stage Dr. Knipp started on a more complete theory set forth in a companion paper[3] which seems capable of accounting fully for the observations.

Pierce's theory considered three mechanisms by which noise could be introduced to the i-f: 1) the "high frequency noise", thought of as shot (and interception) noise in the beam coupled out through the cavity, 2) "low frequency noise" due to amplitude modulation of the oscillator by noise components in the beam at i-f, and 3) frequency modulation due to fluctuations (near i-f) in phase of the returning electrons. Experimentally it seems that with adequate bypassing[4] of the leads to the oscillator tube mechanisms 2) and 3) are relatively unimportant.

Aside from differences in approach, Knipp's theory is an extension of Pierce's consideration of the high frequency noise, 1) in which he takes account a) of the coherence between the first and second passage of the electrons through the gap, and b) of noise due to mixing of various components in the beam with harmonics of the oscillator current. The coherence a) introduces a strong variation with electrical tuning in accord with our results. In most of our experiments noise due to the two sidebands, corresponding to "signal" and "image" in ordinary superheterodyne reception, was measured without any attempt of selection. In Knipp's theory, on the other hand, the two bands are calculated separately and then summed for comparison with experiment. The contributions are in general not equal.

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1. Sherwood and Ginzton, Sperry Gyroscope Co. Report 5520-107
   Beck, Bell Telephone Labs Report MM-42-130-85
   Roach, Standard Telephones and Cables Co. Report 2266 (C) - (WR811)
   Beers, Radiation Lab Report 61-22
2. Pierce, Bell Telephone Labs Report MM-44-140-4
3. Knipp, Radiation Lab Report 873
4. The importance of good bypassing can scarcely be overestimated. Lack of it could introduce astonishing amounts of noise in some circumstances.

Method of Measurement

In most of the prior work on oscillator noise the measurements were made using a resonant cavity filter to remove the noise sidebands from the oscillator output. In the present work this scheme was avoided as we desired to present a non-reactive load to both the mixer and the oscillator under test. Instead the "temperature" of the crystal was measured for various conditions using the set-up shown in Fig. 1, in which the output due to crystal noise was compared with the noise from a resistor of equivalent i-f impedance.

We have the familiar relation for noise figure (in times) of a receiver

$$F = \frac{T_c + F_{IF} - 1}{G_c}$$

where F is the overall noise figure, T_c and G_c the "temperature" and conversion gain of the crystal, and F_{IF} the noise figure of the i-f amplifier. If additional noise power from the local oscillator P_{NX} (in watts for the bandwidth B) is fed to the input we have

$$F' = \frac{P_{NX}}{KTB} + \frac{T_c + F_{IF} - 1}{G_c}$$

$$= \frac{T_c' + F_{IF} - 1}{G_c}$$

where $T_c' = T_c + \frac{G_c P_{NX}}{KTB}$ is an apparent crystal "temperature" including the effects of oscillator noise.

Let P_X be the local oscillator power fed to the crystal and P_N/P the "noise/signal" ratio (noise output power in a band B over oscillator output) for the oscillator. We have $P_{NX} = (P_N/P)\ P_X$. If we measure T_c' under standard conditions, say 0.5 ma crystal current, P_X will vary roughly as $1/G_c$, and to a first approximation $T_c' - T_c$ is proportional to the local oscillator noise ratio P_N/P and not dependent on the properties of the crystal used.

Throughout the X-band measurements we used one crystal which had $G_c = -7$ db and $T_c = 1.2$, and a coupling was always adjusted to give a rectified current of 0.5 ma. The crystal parameters were frequently checked and remained quite constant.

As indicated in Fig. 1, the measuring set consisted of three preamplifiers tuned to 30, 60 and 90 mc, and a main amplifier about 2.5 mc wide tuned to 30 mc which incorporated an i-f attenuator and power output meter. In the case of the 60 and 90 mc preamplifiers a second conversion to 30 mc was employed.

Coupling between the mixer and preamplifier was by a coaxial line transformer so arranged that shifting i-f involved only changing two cables, and did not affect the crystal properties. A noise diode was mounted on the mixer so that F_{IF} could be measured in the three cases.

The tube was mounted on a section 5/8" × 1 1/4" (outside) waveguide with the antenna located centrally in the guide. A choke plunger in the end of the guide was

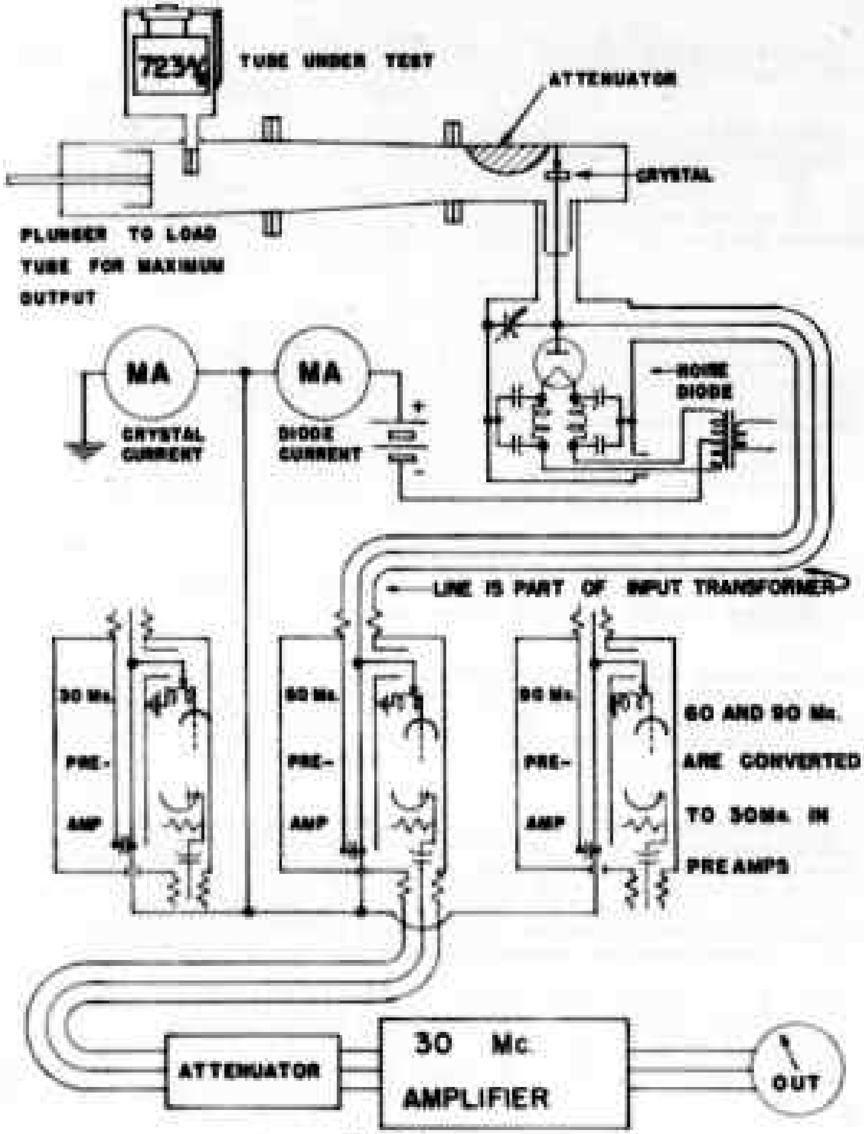
723A/B
TUBE UNDER TEST
ATTENUATOR
CRYSTAL
PLUNGER TO LOAD TUBE FOR MAXIMUM OUTPUT
MA
CRYSTAL CURRENT
MA
DIODE CURRENT
+
-
NOISE DIODE
LINE IS PART OF INPUT TRANSFORMER
30 Mc. PRE-AMP
60 Mc. PRE-AMP
90 Mc. PRE-AMP
60 AND 90 Mc. ARE CONVERTED TO 30Mc. IN PREAMPS
ATTENUATOR
30 Mc AMPLIFIER
OUT

FIG. I

872-3

adjusted for each tube to obtain maximum output. A taper was employed to reduce to ½" x 1" guide and a standard flap attenuator served to adjust crystal current. The crystal holder was of conventional design.

This plumbing was used for most of the measurements reported here and similar arrangements were employed at K-band. To permit separation of the noise side bands in one experiment it was modified by the introduction of a filter cavity on a T connection between the pad and the crystal to reject one component at will. In this case it would have been preferable to avoid changes in crystal gain and i-f impedance by additional padding between the crystal and the T but the local oscillator power was not sufficient to permit this.

Results

The first measurements were a series of controls to establish the validity of the scheme. In these the output power of the 723A/B was varied in some manner not likely to affect the noise output materially, say by changing the resonator voltage, the attenuation was readjusted to give the same crystal current, and P and T_o' were observed at the three i-f's. When T_o' for the center of the electrical tuning range in a given mode (which we have called the "head on" condition) is plotted against 1/P the result is a straight line for each i-f. This line if produced would intersect the ordinate axis at a constant value for T_o, in agreement with the value 1.2 previously determined. A typical plot of this sort is shown as Fig. 2.

It was noticed at once that if the power output of the oscillator was varied by electrical tuning that the plots could no longer be produced back to the common intercept, as indicated by the dotted lines in Fig. 2. Also there was a strong dependence on the direction of electrical tuning, increasing frequency giving increased noise.

Definite asymmetry in noise output as a function of electrical tuning had been observed before (cf. curves in Beers' report) but was apparently ascribed to a peculiarity of the r-f properties of the mixer and more or less ignored. In our experiments no high Q elements were present and the asymmetry was so prominent it could not be passed over, partly because we had the tube tightly coupled to the wave guide.

For convenience we made our measurements generally in three conditions, tuned "head on" and detuned by variation of reflector voltage to the two half-power points (designated as "½ high" and "½ low"). It was soon found that the ratio of the noise outputs at the two half-power points, the "high/low ratio", varied from tube to tube and also depended on mode used and i-f for a given tube. In Table I we illustrate the data obtained on one 723A/B at three i-f's and for five reflector modes, together with the power output and electrical tuning range between half power points.

As might be expected the noise decreases rapidly when the i-f is raised. Indeed the decrease in noise is so marked that not much importance need be attached to the 90 mc data, as the experimental error must be considerable. It should be mentioned that at the half power points the coupling was doubled (to keep the crystal current constant) and therefore if noise output alone is of interest $T_o' - T_o$ for the half power points should be divided by 2.

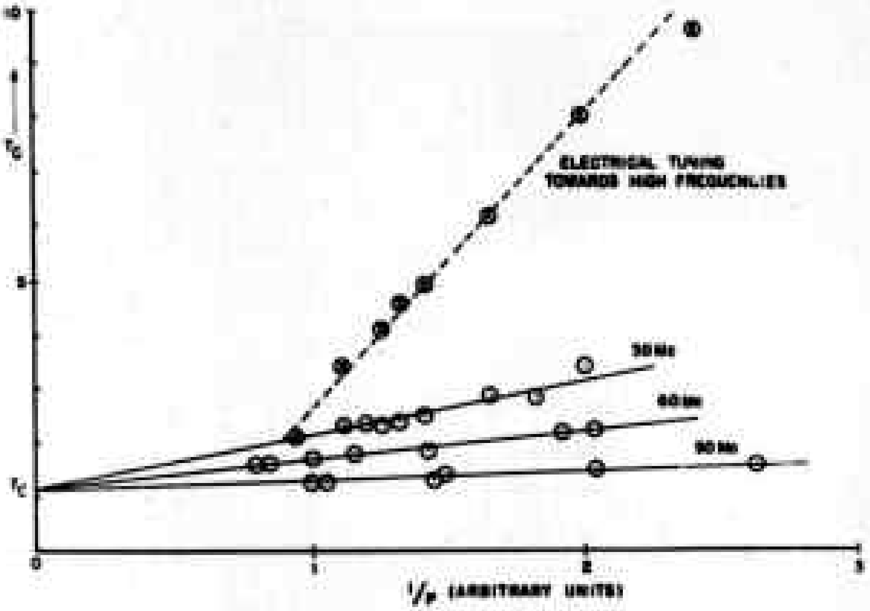
10
8
T_C
5
T_C
ELECTRICAL TUNING
TOWARDS HIGH FREQUENCIES
30 Hz
60 Hz
90 Hz
0
1
2
3
$1/_P$ (ARBITRARY UNITS)

FIGURE 2

Table I

Tube #[illegible] (T.E.)   Act. [illegible] = 200 T_r = [illegible] I_b = .3 ma

Reflector Mode	30 kc. $T_d' - T_d$ Head on	30 kc. $T_d' - T_d$ ½ high	30 kc. $T_d' - T_d$ ½ low	high/low	60 kc. $T_d' - T_d$ Head on	60 kc. $T_d' - T_d$ ½ high	60 kc. $T_d' - T_d$ ½ low	high/low	90 kc. $T_d' - T_d$ Head on	90 kc. $T_d' - T_d$ ½ high	90 kc. $T_d' - T_d$ ½ low	high/low	P Power output mw.	Electrical Tuning Range mc.
"45 mils"	165.	715.	160.	1.6	73.	140.	130	1.1	36.	66.	48.	.7	.06	75
"75 mils"	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
"100 mils"	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
"125 mils"	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
"250 mils"	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

	P_s (units 10^{-13} watts)			P_s (10^{-13} watts)			P_s (10^{-13} watts)		
45 mils	177	306	235	42.4	60	91	31	19.7	20
75 mils	[illegible]	91	[illegible]	[illegible]	34	[illegible]	[illegible]	[illegible]	[illegible]
100 mils	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
125 mils	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
250 mils	196	202	[illegible]	[illegible]	63	[illegible]	[illegible]	[illegible]	[illegible]

The results for the "45 volt" mode appear less startling when one takes into account the variations in power output. In the lower half of the table we show the noise power in units of 10^{-13} watts computed from the relation $P_n = \frac{T_n' - T_n}{\theta} \frac{P}{P_x} kTB$, using $T = 292°K$, and a bandwidth of 2.5 mc.

Thus the figures for P_n represent the actual noise power coming out of the tube in the two 2.5 mc wide bands located symmetrically about the frequency of oscillation at a distance equal to the i-f for the various conditions listed. Each figure is the sum of the power in the two sidebands, which as we shall see later, are in general not equal. It must be remembered that at the ½ power points the noise/signal ratio $P_N/_P$ will be poorer since the useful power P will be decreased by a factor of 2.

Apart from the 45 volt mode there seems to be a regular trend downward in noise power as the transit angle is increased. Because of the very low power obtained in the 45 volt mode it was not possible to use adequate padding between the oscillator and crystal so results for this mode may be in error due to resonance effects. Also in the 45 volt mode the electrons penetrate close to the reflector and the focusing may be badly upset.

Normally we find that the "high/low ratio" is greater than unity but in the case of the 45 volt mode at 90 mc i-f we find a ratio of only .68. This anomalous behavior was occasionally found in other tubes at both K and X bands and has been reported by N. E. Miller of B.T.L. Knipp's theory predicts these ratios in cases of extremely light loading such as would be found here at the 45 volt mode when the loading was correctly adjusted for the 160 volt mode.

In Table IIa we summarize results obtained for a representative group of 723A/B tubes, all in the "105 volt" reflector mode and with a 30 mc i-f. Values of $T_o' - T_o$ are given for the "head on" condition and at the two half power points, in columns three to five. Column six gives the high/low ratio and seven the power output in milliwatts. Next we have I_o, the useful current, which makes a second trip through the gap after reflection, which was estimated from the observed cathode current I_k (column 9). In the tenth column we give the electrical tuning range between half power points, and in the last the noise power P_n for the head on condition computed as before.

The tubes reported here were selected to represent the widest variations in overall performance that we could find in our stock, excluding those which were obviously rejects. The estimate of I_o was formed from observations a) of the cathode and reflector current when the reflector was positive and collecting all electrons which made one trip through the cavity and b) of the cathode current with negative reflector. Ignoring effects of secondaries (which is surely a questionable procedure) we could compute transparencies of the three grids (G_2 and G_3 are similar). These turned out to be in quite good agreement with the optical transparencies, which is our only justification for neglecting the secondaries. With these data the current which was reflected and made a second trip through G_3 could be estimated. Obviously only this current counts for power production, although noise and beam loading can, of course, be contributed by the current which gets past G_2 on its first trip. In many cases operation at positive reflector liberated considerable gas, so all tubes were put through a suitable aging before measurements were made.

We find that although power output varied over a range of almost 2:1 and electrical tuning varied over a range of about 2.5:1, the noise at head on varied about 4:1. So far we have not found any direct correlation between noise output and any of the other quantities recorded.

Table IIA

i-f = 30 mc. "105 volt" mode 723A/B

Tube	Mfr.	$T_r' - T_r$ Dead on	$T_r' - T_r$ f high	$T_r' - T_r$ f low	$\delta I/I_b$	Power Output	"T_e"	I_b	Electrical Tuning Range	R_n
[illegible]	W.E.	1.8	3.1	3.1	2.7	27.1 mw	[illegible] ma	[illegible] ma	[illegible] mc	[illegible] x 10^{-13} v
[illegible]	W.E.	1.8	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	W.E.	1.8	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	W.E.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	W.E.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	W.E.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	W.E.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	W.E.	[illegible]				[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	W.E.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	W.E.	[illegible]				[illegible]	[illegible]	[illegible]		[illegible]
[illegible]	W.E.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	W.E.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
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[illegible]	W.E.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	W.E.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	W.E.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	Raytheon	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	Raytheon	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	Raytheon	[illegible]				[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	Raytheon	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	Raytheon	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	Raytheon	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	Kenlad	[illegible]				[illegible]	8.9	22.7		[illegible]
[illegible]	Kenlad	1.8				24.3	16.6	20.9		[illegible]
[illegible]	Kenlad	[illegible]				20.4	6.5	19.3		[illegible]
[illegible]	Kenlad	[illegible]				22.5	17.5	20.4		[illegible]
Average		2.39	9.25	5.495	2.21	21.06	14.83	19.21	46.5	49.1

In Table IIb we give similar data (omitting the current measurements) for some K-band tubes, mostly 2K32's with a couple of 5022A's shown for comparison although they are now obsolete. These were measured with 30 mc i-f and in a reflector voltage mode occurring near 200 volts. It is not at all certain that we were using the same drift angle in all cases. In this case the crystal had a conversion loss of 8.2 db and a noise temperature of 2.

As is only to be expected, the noise is increased since the ratio of i-f to r-f is smaller and a large increase in Q of the oscillator is very unlikely. If we compute the noise to signal ratio, P_N/P, for the case of 3.5 mc bandwidth at 30 mc i-f (two sidebands) we find an average of 5.1×10^{-10} at K band contrasted with 2.33×10^{-10} at X. Considering only the ratio of i-f to r-f in the two cases one would expect a larger difference. The implication is that the loaded Q of the 2K33 tube is somewhat higher than that of the 723A/B, and this is borne out to some extent by the fact that the electrical tuning range is only slightly greater at K-band. In any event there is no real basis for the general impression that K-band tubes are "noisy".

It should be pointed out that in cases where marked electrical tuning hysteresis was present the noise was greatly increased. This may well be due to a combination of effects such as heavy reactive loads and multiple transits. Because of the great difficulties due to instability no quantitative work in the hysteresis region was attempted.

Measurements made on a 723A/B with a rejection filter to eliminate one sideband are presented in Figs. 3 and 4 for 30 and 60 mc i-f respectively. The filter used was of course not perfect and an empirical correction was used to allow for the "leakage" that got past it. The validity of this procedure is shown by the fact that the measured curve for both sidebands agrees quite well with the sum of the two separated sidebands. Points were taken with the electrical tuning "head on" and detuned to the 3/4, 1/2 and 1/4 power points on each side. Note that at head on, the two sidebands are by no means symmetrical. This at first made us think we had chosen the center of the mode incorrectly, until we learned that Knipp predicted just this effect.

The vertical broken lines represent the limits of oscillation. We were unable to make good measurements much below the 1/4 power points, so we have sketched in the rest of the curves as predicted by Knipp's theory. We see now that the high-low ratio is principally due to the behavior of the low frequency sideband.

The effect of load variations on the noise output of a 723A/B is shown in Fig. 5, which is an admittance plot with the plane of reference at the grids of the tube[5]. This was taken at 30 mc i-f, and the sidebands were not separated. The reflector voltage was set at the center of the mode at matched load. The numbers give noise power in arbitrary units. As might be expected the noise is least for light loads and increases to very high values near the sink.

Note that the noise contours do not follow the conductance lines exactly, but that the tube is more noisy for inductive loads. This is a consequence of the long line effect plus the fact that the two sidebands contain different amounts of noise power. For each point on the diagram representing a particular load admittance we observed the power due to two sidebands. Because the load was not really at the grids but was actually several wavelengths away, the loads seen by the two sidebands 30 mc above and below the center frequency were appreciably different. Taking this effect into account and using Knipp's curves for the power in the two sidebands as a function

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[5] For a discussion of the method of representation see RL Report No. 717, Notes on Load Effects on Reflex Oscillators

Table 15b

i-f = 30 mc "200 milli" mode

Tube	Type	$T_B' - T_E$ Read on	$T_B' - T_E$ ½ low	$T_B' - T_E$ ½ high	Δf/fo	Power Output	Electrical Tuning Range	F_N
295	2K33	2.9	5.0	13.3	2.6	35.4 mw	59 mc	135×10^{-13} w
[illegible]	"	3.8	7.7	23.7	1.7	[illegible]	[illegible]	321
[illegible]	"	3.7	7.4	20.	2.7	37.0	66	132
[illegible]	"	3.4	5.0	15.2	1.7	46.0	77	233
[illegible]	"	4.3	6.2	[illegible]	1.8	[illegible]	31	96
[illegible]	"	3.7	6.8	10.8	1.7	12.5	52	80
[illegible]	"	5.2	23.	31.	1.5	20.2	76	204
[illegible]	"	5.5	15.	27.	2.0	13.1	54	139
[illegible]	"	2.9	6.9	34.	3.0	47.	71	180
[illegible]	"	6.0	7.2	21.	11.	20.2	50	240
[illegible]	"	3.0	9.7	23.	2.4	5.0	47	33
[illegible]	"	4.1	9.3	27.	2.0	42.	66	247
Average	"	4.41	9.7	23.6	2.78	27.6	56.7	155
#32	SR42A	3.7	5.9	10.3	1.7			
#974	"	12.0	43.	40.	1.7		46.4	

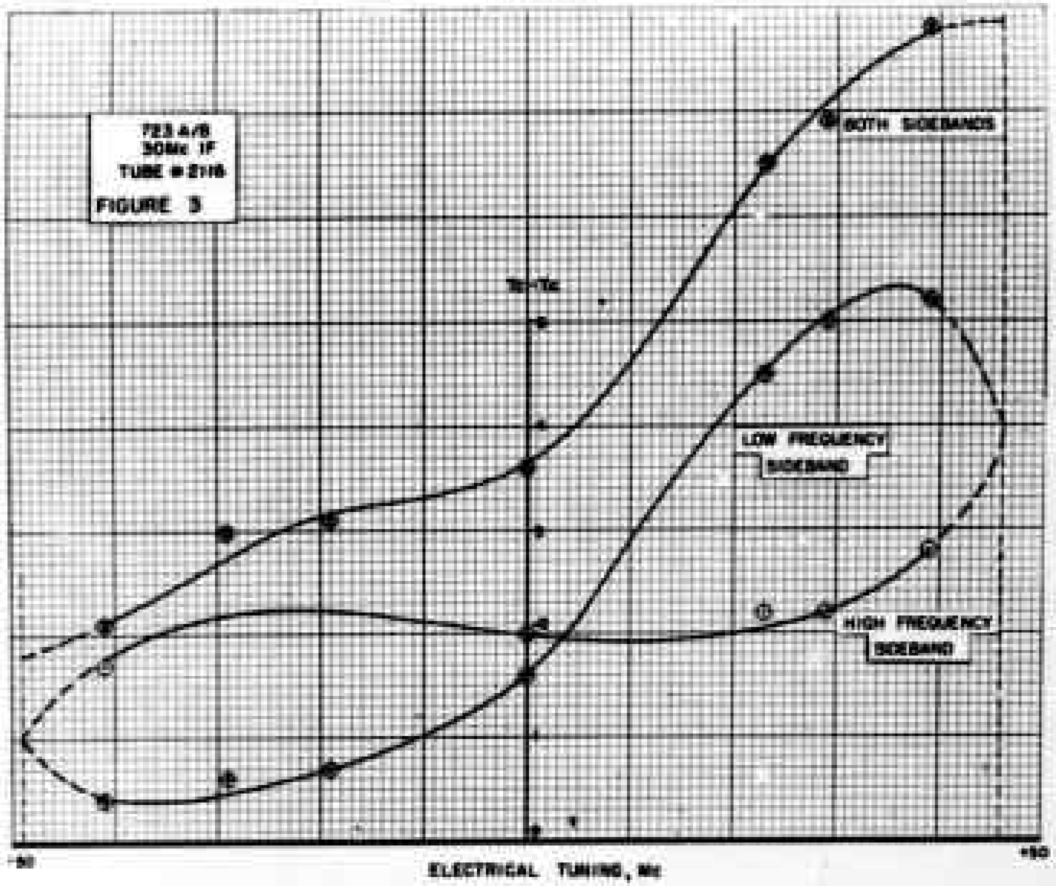
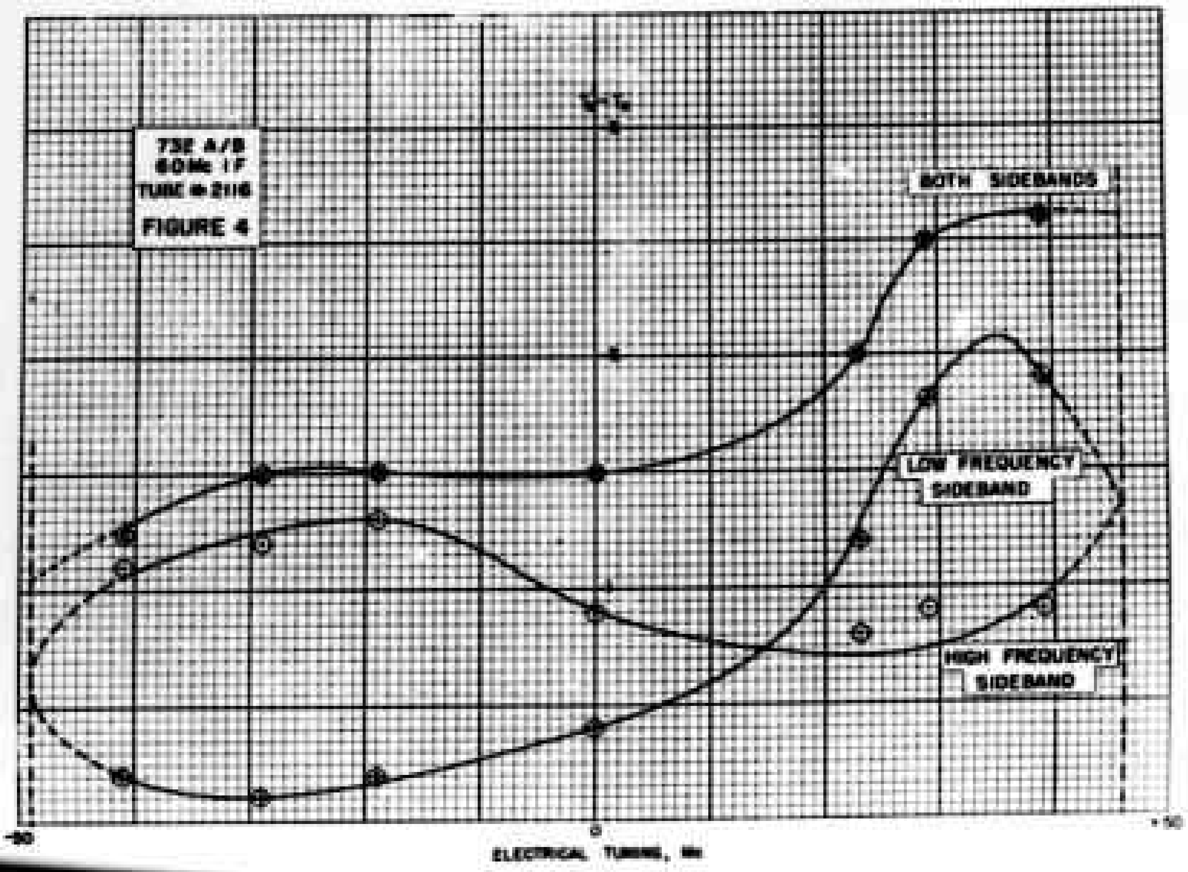

723 A/B
30Mc IF
TUBE # 2116
BOTH SIDEBANDS
LOW FREQUENCY SIDEBAND
HIGH FREQUENCY SIDEBAND
To-Tc
-50
+50
ELECTRICAL TUNING, Mc

FIGURE 3


73E A/B
60Mc IF
TUBE # 2116
FIGURE 4
BOTH SIDEBANDS
LOW FREQUENCY SIDEBAND
HIGH FREQUENCY SIDEBAND
-50
0
+50
ELECTRICAL TUNING, Mc

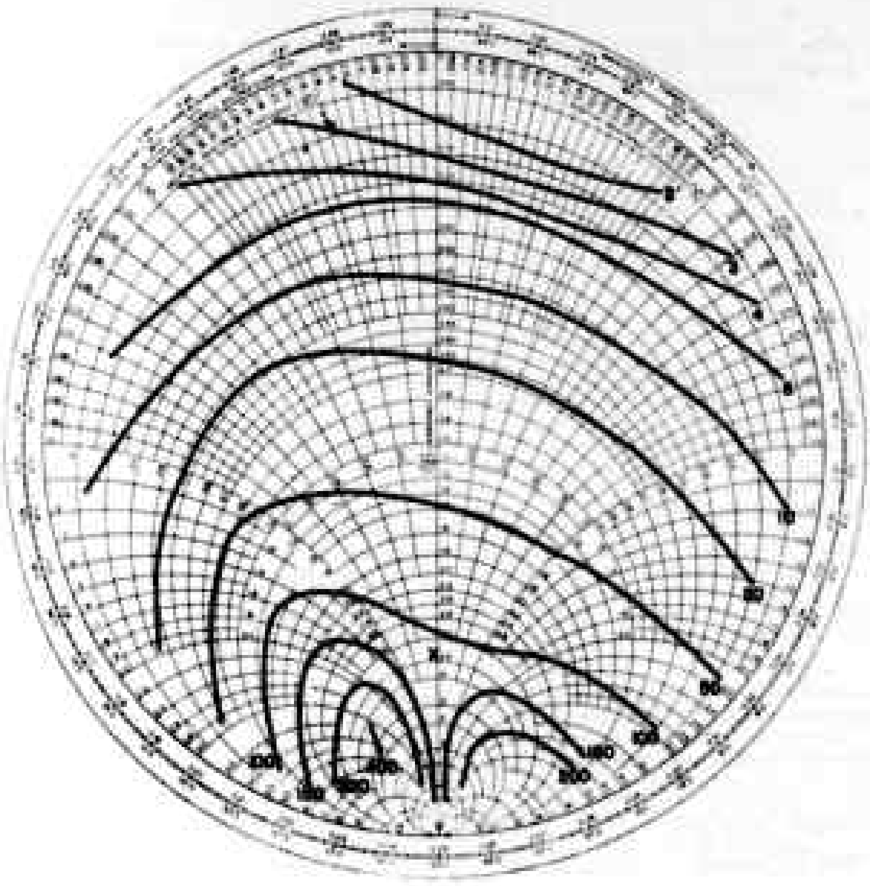


FIGURE 5 NOISE OUTPUT OF A 723 A/B AS A FUNCTION OF LOAD ADMITTANCE. I.F. 30 MC, BOTH SIDEBANDS. NUMBERS ARE % MAX POWER X (Tc'-Tc) WHERE (Tc'-Tc) ARE IN TEMP. UNITS. THE CROSS INDICATES THE MAXIMUM POWER POINT.

of load conductance we could compute the theoretical diagram shown in Fig. 6. This is drawn for a hypothetical tube. The scale again is in arbitrary units. Note the strong resemblance in the shape of the contours to those found experimentally.

Discussion

The rather high values shown in Tables I and II under P_e, ranging upward of 10^{-11} watts, should not cause undue alarm since it must be remembered that in operating receivers there will be several factors reducing the amount of this noise reaching the receiver input. In the first place, the decoupling used to adjust the excitation for the mixer will operate on the noise sidebands also, and ordinarily to the same extent.

Second, many converters have a tuned circuit in the input (e.g. a tunable TR box) which profoundly affects results. If the Q is sufficiently high, and the box is tuned for signals, local oscillator frequency and image frequency will be reflected well. If the phase of the reflected local oscillator voltage is right to add to the direct wave at the crystal it will be possible to decouple by 6 db more than if local oscillator is fed in through a matched line as in these experiments. At the same time one noise sideband (that at image frequency) will be similarly reinforced. The sideband at signal frequency will be transmitted through the TR, leaving only the direct wave, so there will be a net reduction in noise power converted. The amount of this improvement can readily be computed for any specific case. The results depend strongly on the parameters chosen, but reductions of 25 to 50% are common. It is perhaps interesting to note that the common practice of putting the local oscillator on the high frequency side of the signal (so that the low frequency sideband is reduced) tends to minimize the increase in noise figure with electrical tuning. With this arrangement the noise figure would be slightly poorer at the center of the mode but would not decay nearly as fast when electrical tuning toward higher frequencies is required.

Third, the load seen by the oscillator itself may not be as heavy as we used. Oscillators are often underloaded for the sake of securing more uniform output over a wide tuning range. From Fig. 5 we see that comparatively small changes in load which would not materially affect the power output may make considerable differences in the noise.

J. B. H. Kuper
M. C. Waltz
October 30, 1945

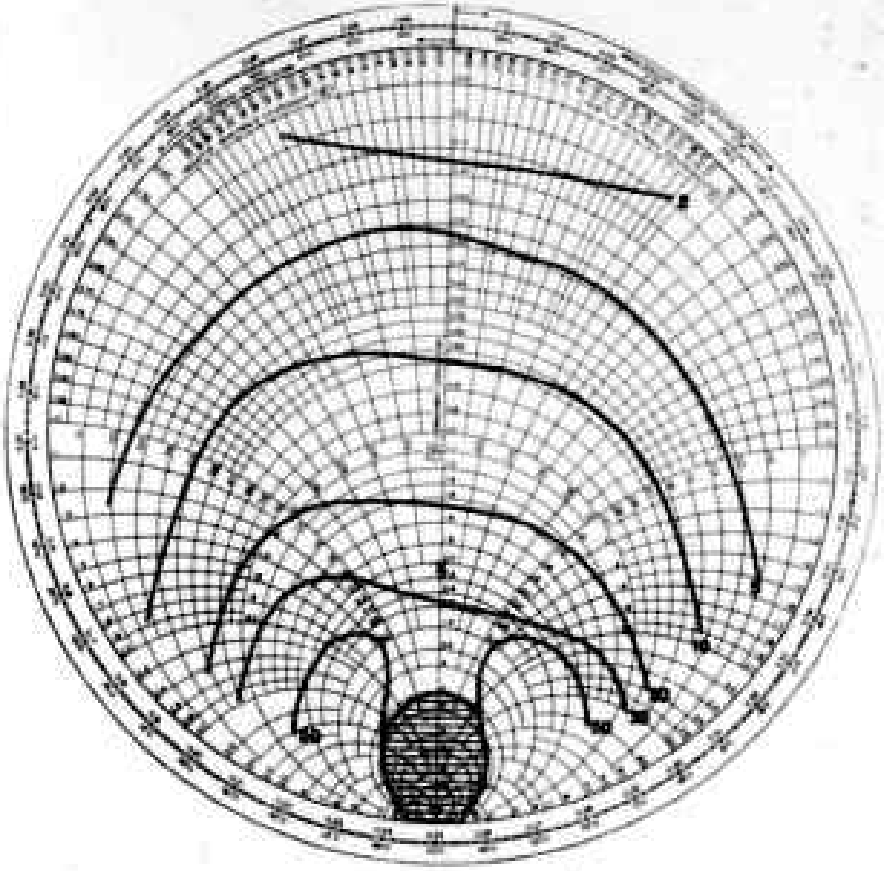


FIGURE 6 NOISE COUNTOURS FOR 30MC I.F., HYPOTHETICAL TUBE, LINE 3λ LONG. UNITS ARE 10 × F × g, WHERE F IS FROM KNIPP'S REPORT, AND g IS CONDUCTANCE AT GRIDS NORMALIZED TO ONE AT SINK. THE CROSS INDICATES MAXIMUM POWER POINT.

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Kuper, J.B.H.

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ABSTRACT:

A program of measurements on noise output of reflex local oscillators, particularly the 723A/B and 2K33, was undertaken to determine the importance of this factor in receiver design. Considering the two noise sidebands each 2.5 mcps wide and located 30 mcps away from the main output, noise powers ranging from 2.2 to 9.8×10^{-12} watts coming out of 723A/B's were found when loaded for optimum output. Asymmetrical behavior of the noise with electronic tuning was investigated and found to require the new theory presented in the report to follow. Some measurements of the individual noise sidebands and of the noise output as a function of load were found to be in satisfactory agreement with theory.

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